The Molecular Spiral Arms of NGC 6946

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A current interest in the study of star formation in galaxies has centered around the possible relationship between spiral density waves and the star formation efficiency. It is believed that in our galaxy most of the massive star formation occurs in spiral arms (Georgelin and Georgelin 1976). Recently, there has been a series of studies completed which suggest that the primary effect of a spiral density wave is to organize the ISM into a global spiral pattern (*e.g.* Scoville, Sanders, and Clemens (1986)), and that the observed spiral variations in the OB star formation efficiency on the spiral arms is due to orbit crowding in the spiral potential. In this picture the concentration of molecular gas is a purely kinematic concentration, and star formation in the arms results from cloud-cloud collisions (Scoville and Hersh (1979); Kwan and Valdes (1983)).

From ^{12}CO(J=1→0) observations at 45″ resolution Tacconi and Young (1989) have found evidence for enhancements in both the CO emissivity and the massive star formation efficiency (MSFE) on optical spiral arms of the bright spiral galaxy NGC 6946. In the optically luminous and well-defined spiral arm in the NE quadrant, there are enhancements in both the H_2 surface density and MSFE relative to the interarm regions. In contrast, a poorly defined arm in the SW shows no arm-interarm contrast in the MSFE.

To further investigate the molecular gas content of these two spiral arms, we have made ^{12}CO J=2→1 and 3→2 observations with the James Clerk Maxwell Telescope. In the J=2→1 line, we have made observations of the NE and SW spiral arm and interarm regions in 4×9 10″ spaced grids (36 points per grid). Because of decreased sensitivity in the J=3→2 line, we were limited to mapping the two arm regions in 2×3 10″ spaced grids (6 points per grid). The centers of each of the grids lie 2.4′ to the NE and 2.3′ to the SW of the nucleus of NGC 6946.

With the CO J=2→1 data, we are able to fully resolve the two observed spiral arms in NGC 6946. In both cases the CO emission is largely confined to the optical spiral arm regions with the peak observed T_A^* being up to 4 times higher on the spiral arms than in the interarm regions. In Figure 1, sample J=2→1 spectra from both the arm and interarm regions of the northeast and southwest arms are shown. Typical J=2→1 integrated intensities ($\int T_A^* dv$) on the bright northeast spiral arm are 7 K km s^{-1}, dropping to <1.5 K km s^{-1} in the interarm regions. For the southwestern arm region, J=2→1 integrated intensities of 4.5 and 2.1 K km s^{-1} are typical for positions which are on and off the spiral arm, respectively. Figure 2 shows spectra from both arms in the J=3→2 line. For this higher transition emission, peak antenna temperatures (T_A^*) observed on the northeast spiral arm are 2–3 times higher than those on the southwest arm.

We are currently estimating massive star formation efficiencies on and off the spiral arms through direct comparison of the CO maps with an Hα image. We are also comparing the CO J=2→1 data with an HI map made at similar resolution. Thus, we will be able to determine structure in all components of the ISM on scales of <20″. The spatial resolution of the CO data coupled with the good velocity resolution will allow us to determine the effects of the spiral potential on the molecular gas kinematics. Observed kinematic differences between the NE and SW arms may provide clues to the reasons for the different MSFE's of these two regions.

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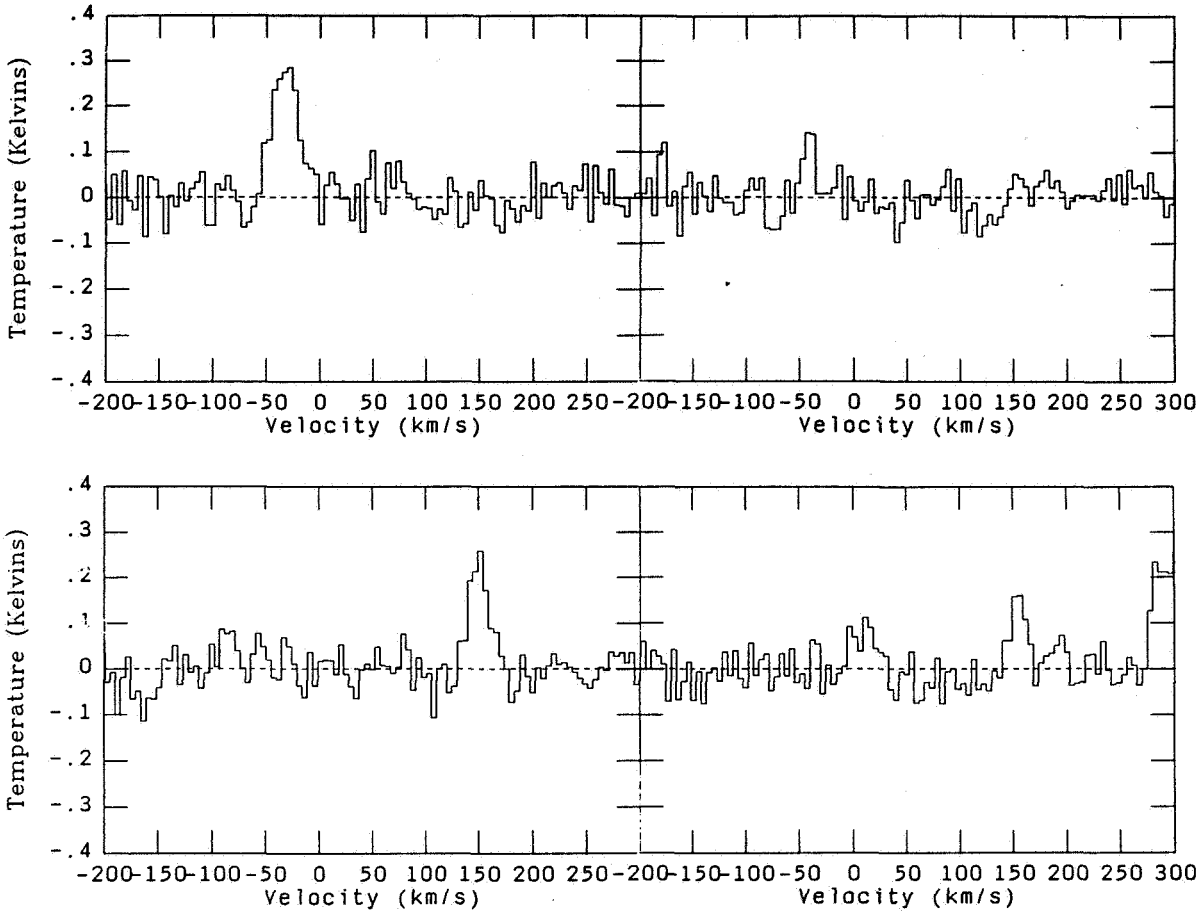

Figure 1: Sample J=2→1 spectra from the spiral arm and interarm regions of NGC 6946. Spectra from the NE spiral arm are shown in the upper left (on arm spectrum) and right (off arm spectrum). Spectra from the SW are similarly shown in the lower left and right panels.

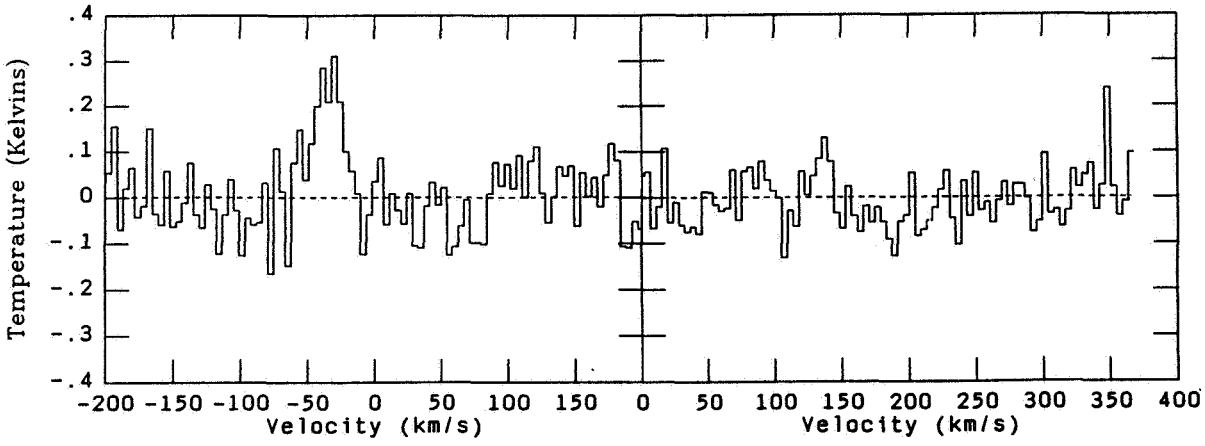

Figure 2: Sample J=3→2 spectra from the two observed spiral arms in NGC 6946. A spectrum from the NE arm is shown on the left, while an example from the SW arm is presented in the right panel.